

CLAIMS

We claim:

- 1 1 A method of chemical-mechanical jet etching of patterned features in a
2 semiconductor workpiece, by impinging a machining etchant fluid upon a surface
3 of said workpiece, whereby material is removed from said surface of said
4 workpiece at an etch rate of at least about 10 microns per minute, forming three-
5 dimensional features thereon.
- 6 2. The method of Claim 1, wherein such workpiece comprises a material selected
7 from the group consisting of a silicon wafer or gallium arsenide or other
8 semiconductor substrate, silicon-on-insulator ("SOI"), SiO₂, glass, quartz, pyrex,
9 ceramic, or glass bonded to a substrate, conductor, or insulator.
- 10 3. The method of Claim 1, wherein said workpiece is first masked with a patterned
11 protective mask, such that material is selectively removed from said surface only
12 in areas which are not covered by said mask.
- 13 4. The method of Claim 1 or Claim 3, wherein said machining etchant comprises a
14 slurry of solid particulate material in a liquid.
- 15 5. The method of Claim 4, wherein said slurry is a suspension or dispersion.
- 16 6. The method of Claim 1 or Claim 3, wherein said machining etchant comprises
17 solid particulate material in a carrier gas stream.
- 18
19 7. The method of Claim 4, wherein said liquid is a chemical etchant for the material
20 of said workpiece.

- 21 8. The method of Claim 4, wherein said liquid is not a chemical etchant for said
22 workpiece material, but acts as a solvent for a compound which is a chemical
23 etchant for the material of said workpiece..
- 24 9. The method of Claim 7, wherein said chemical etchant is a compound selected
25 from the group consisting of KOH, NaOH, HF, HNA(an aqueous solution of
26 about 7 wt % HF, about 30 wt.% HNO₃, and about 10 wt.% CH₃COOH),TMAH
27 (Tetramethyl Ammonium Hydroxide), EDP (Ethylene Diamine Pyrochatechol),
28 amine gallates.
- 29 10. The method of Claim 1or Claim 3, wherein said machining etchant is delivered to
30 a surface of said workpiece by one or more nozzles.
- 31 11. The method of Claim 4, wherein said machining etchant is delivered to a surface
32 of said workpiece by one or more nozzles.
- 33 12. The method of Claim 6, wherein said machining etchant is delivered to a surface
34 of said workpiece by one or more nozzles.
- 35 13. The method of Claim10, wherein one or more of such nozzles is a dual nozzle,
36 having a central orifice surrounded by an annular orifice, through which orifices
37 jets of either a single type of machining etchant or of two different types of
38 machining etchants can be delivered to the workpiece surface.
- 39 14. The method of Claim 13, wherein a selection of pressures and viscosities of a
40 first machining etchant supplied to the central orifice and a second machining

41 etchant supplied to the annular orifice of said at least one dual nozzle, results in
42 distinct inner and outer jets, whereby the outer jet confines the inner jet to a
43 narrower dimension than would occur in the absence of the outer jet.

44 15. The method of Claim 10, wherein said machining etchant is delivered to the
45 surface of said workpiece as said nozzle or nozzles and such workpiece are
46 rotated, translated, or rastered relative to one other.

47
48 16. The method of Claim 1 or 3, wherein said machining etchant is delivered to the
49 surface of said workpiece as said workpiece is rotated, translated, or rastered past
50 said nozzle or nozzles, which are stationary.

51 17. The method of Claim 1 or 3, wherein said machining etchant is delivered to the
52 surface of said workpiece as said nozzle or nozzles are rotated, translated, or
53 rastered past said workpiece, which is stationary.

54 18. A method of chemical-mechanical jet etching a semiconductor workpiece, by
55 impinging a machining etchant fluid upon a surface of said workpiece, whereby
56 workpiece material is removed uniformly from said surface of said workpiece,
57 whereby the thickness of said workpiece is uniformly decreased from its original
58 value to a desired smaller thickness, at a minimum etch rate of at least about 10
59 microns per minute.

60 19. The method of Claim 18, wherein such workpiece comprises a material selected
61 from the group consisting of a silicon wafer or gallium arsenide or other
62 semiconductor substrate, silicon-on-insulator ("SOI"), SiO₂, glass, quartz, pyrex,
63 ceramic, or glass bonded to a substrate, conductor, or insulator.

- 64 20. The method of Claim 18, wherein said machining etchant comprises a slurry of
65 solid particulate material in a liquid.
- 66 21. The method of Claim 20, wherein said liquid is a chemical etchant for said
67 workpiece material.
- 68 22. The method of Claim 20, wherein said liquid is not a chemical etchant for said
69 workpiece material, but acts as a solvent for a compound which is a chemical
70 etchant for said workpiece material.
- 71 23. The method of Claim 20, wherein said dissolved chemical etchant is a compound
72 selected from the group consisting of KOH, NaOH, HF, HNH, TMAH
73 (Tetramethyl Ammonium Hydroxide), EDP (Ethylene Diamine Pyrochatechol),
74 amine gallates. .
- 75 24. The method of Claim 18, wherein said machining etchant comprises solid
76 particulate material in a carrier gas stream..
- 77 25. The method of any of Claims 18, 20, or 24, wherein said machining etchant is
78 delivered to the surface of said workpiece by one or more nozzles.
- 79 26. The method Claim 20, wherein at least one of such nozzles is a dual nozzle,
80 having a central orifice surrounded by an annular orifice, through which orifices
81 either a single type of machining etchant or two different types of machining
82 etchants can be delivered to the workpiece surface.

- 83 27. The method of any of Claims 18, 20, or 24, wherein said machining etchant is
84 delivered to the surface of said workpiece as said nozzle or nozzles and such
85 workpiece are rotated, translated, or rastered relative to one other.
- 86 28. An apparatus which performs jet etching on semiconductor workpieces, said
87 apparatus comprising:
88 a) at least one ejector device which projects a machining etchant fluid
89 onto a surface of a semiconductor workpiece, whereby material is etched
90 from said workpiece surface, wherein said ejector device is oriented with
91 respect to said workpiece surface;
92 b) a holding device which secures said workpiece in said oriented position
93 relative to said ejector device while said workpiece surface is etched;
94 c) a delivery system which delivers said machining etchant fluid to said at
95 least one ejector device.
- 96 29. The apparatus of Claim 28, wherein said at least one ejector device is an array of
97 ejector devices.
- 98 30. The apparatus of Claim 29, wherein said ejector device comprises a spray nozzle.
- 99 31. The apparatus of Claim 28, wherein said ejector devices comprise at least one
100 dual nozzle, in which a central orifice for discharge of machining etchant is
101 surrounded by an outer, annular orifice through which machining etchant is also
102 discharged.
- 103 32. The apparatus of Claim 31, wherein a selection of pressures and viscosities of a
104 first machining etchant supplied to the central orifice and a second machining

105 etchant supplied to the annular orifice of said at least one dual nozzle, results in
106 distinct inner and outer jets, whereby the outer jet confines the inner jet to a
107 narrower dimension than would occur in the absence of the outer jet.

108 33. The apparatus of Claim 27, wherein said holding device comprises a rotating
109 mechanism whereby said workpiece is rotated during said jet etching.

110 34. The apparatus of Claim 27, wherein said holding device comprises a moving
111 mechanism whereby said workpiece is translated and/or rastered with respect to
112 the ejector device during said jet etching. .

113 35. The apparatus of Claim 27, wherein said delivery system comprises an injector
114 bar along which an array of nozzles is disposed.

115 36. The apparatus of Claim 27, including a system which captures effluent
116 machining etchant fluid and returns said etchant fluid for reuse.

117 37. The apparatus of Claim 30, wherein said delivery system comprises at least two
118 separate pumps, for delivering machining etchant fluid separately to the central
119 orifice and the annular orifice of the at least one dual nozzle.

120 38. The apparatus of Claim 27, in which the delivery system includes provisions for
121 delivery of the machining etchant fluid in pulsed fashion, rather than continuous
122 flow.